INCINERATION OF ION EXCHANGE RESINS FROM NUCLEAR POWER PLANTS

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ABSTRACT

Incineration of loaded radioactive resins from loop purification is under development in the Juelich Research Center. It is based on the Juelich Incineration Process. The first experimental results show that a mass reduction factor of 100 can be obtained. This indicates low disposal costs. The thermal and chemical stability of the resulting product is high. The development aims at the demonstration of a pilot plant being operated with original resins from nuclear power plants under remote conditions.

INTRODUCTION

The purification of cooling loops of nuclear power plants produces radioactively loaded ion exchange resins. Contrary to conventional water purification, they will not be regenerated but removed after being loaded. Pressurized water reactors with 1,200 MW electrical power produce about 3 m^3 spherical type resins per year, with an activity load ranging between 4 E 11 and 1 5 E 13 Bq/m^3. The same size boiling water reactors produce about 10m^3 powder type resins per year being loaded in the range of 4 E 11 and 1.5 E 12 Bq/m^3.

The common processes developed for the treatment of the loaded resins are:

- Solidification in concrete, bitumen or a plastic matrix and
- Filling up in vessels either wet or after drying.

Advanced processes are:

- Compaction at elevated temperature and
- Incineration.

Incineration appears to be a promising option to turn the resins into an optimum final waste form because it will minimize the waste volume and because the secondary waste products are chemically stable and can be solidified using well established processes. As a result of the volume reduction the specific activity will rise. Therefore, incineration has been regarded as suitable for the treatment of low active resins only.

In the Juelich Research Center, experiments have begun in order to develop a process suitable for the incineration of all kinds of resins not only those in the low activity category.

EXPERIMENTAL PLANT

Based on the idea of the controlled multi-stage incineration, according to the Juelich Incineration Process (1), an experimental plant has been constructed. The resulting principle is explained in Fig. 1.

The resins are dried and partly decomposed passing through zones with increasing temperatures in the decomposition chamber. The hot off-gas circulating in the heat jacket of this chamber is the heat source for evaporation and gasification. The resins rest on a turning bottom plate which leaves an adjustable gap to allow the resins to fall into the burner. The gases pass through the lower part of the bulk and enter the burner through the gap between the bottom plate and the wall of the decomposition chamber. The flow conditions can be adjusted by the pressure in the burner and at the top of the decomposition chamber and are also influenced by the heat gradient along the decomposition chamber. The throughput is regulated by the rotation of the bottom plate and by the gap width. Mixing elements on the shaft of the bottom plate prevent pasting of the resins. The partly decomposed and carbonized resins fall to the hopper-shaped bottom of the burner. They will completely be burnt in the countercurrent air stream entering the burner at that point. In the secondary cyclone burner, the oxidization will be completed and entrained ash particles will be separated.

The throughput of the experimental plant during the first campaign varied between 10 and 15 kg wet resins per hour. About 400 kg of mixtures of loaded but non-radioactive anion and cation exchangers originating from conventional water purification have been treated. Their water content was 50% weight.

The results of the first campaign show that the potential advantages of the process can be put into practice:

- Separate dewatering or other kind of pretreatment of the resins is not necessary,
- Additional substances to support the process are not necessary,
- Each separate stage of the process can be optimized by itself,
- The secondary products are chemically stable,
- The throughput is variable, and
- The off-gas volume is reduced to a minimum.

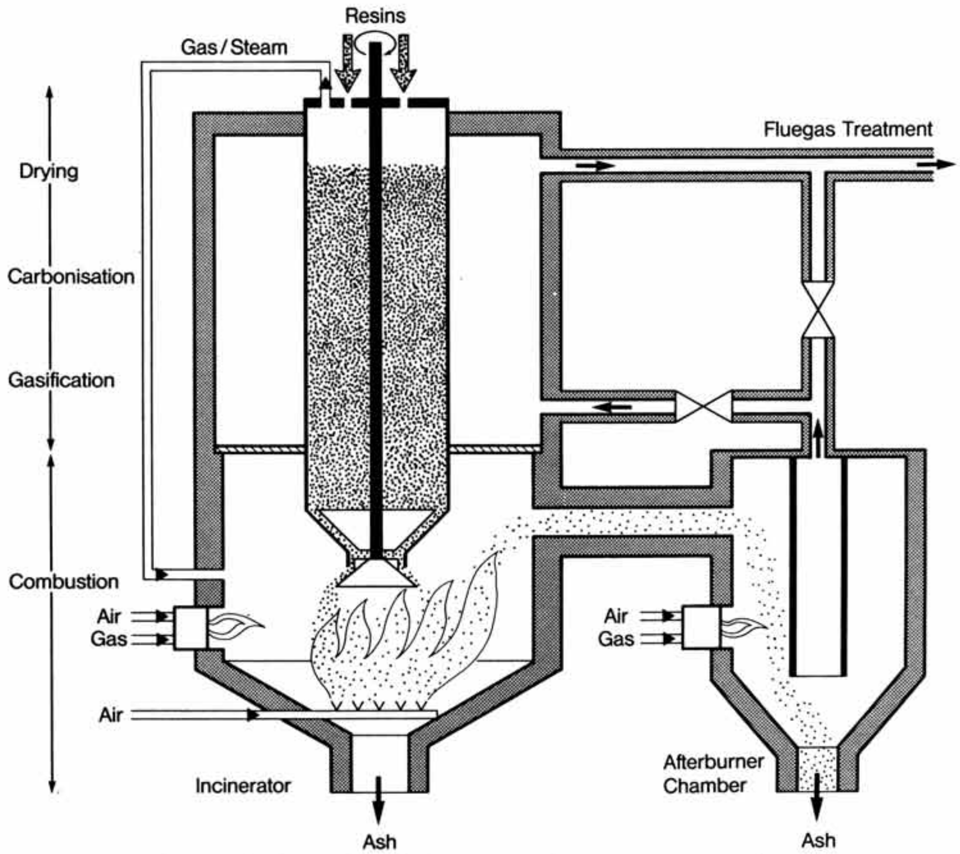

Fig. 1. Principle of the incineration of ion exchange resins.

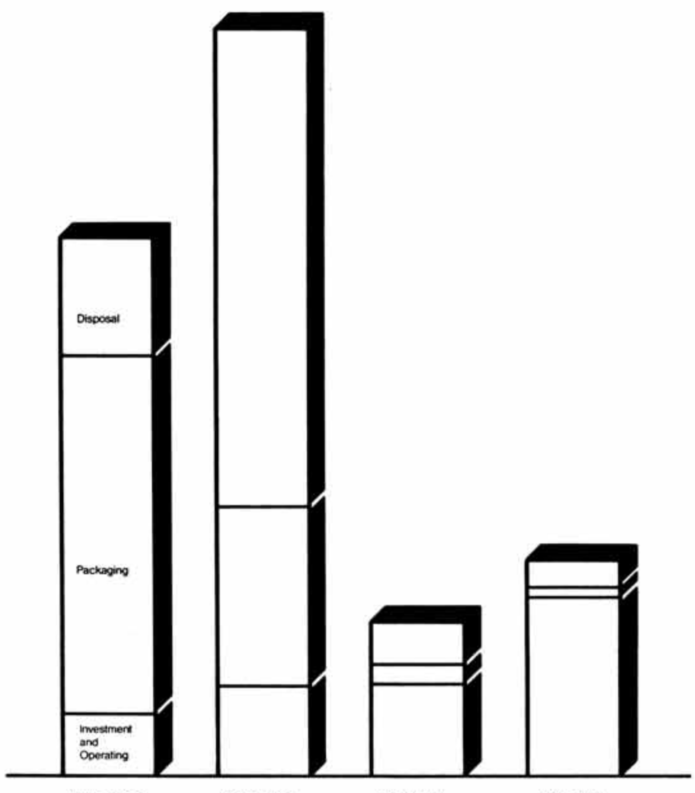

Fig. 2. Economy of different processes for the treatment of ion exchange resins.

The specific throughput related to the equipment volume is high. Therefore, the construction of mobile incinerators and of compact units suitable for the installation in hot cells is possible.

The mass reduction factor was found to be 50 to 100.

PILOT PLANT

Construction and operation of a 10 kg/h pilot plant will follow. The final phase of the developmental program will include the incineration of original radioactive resins from nuclear power plants under remote conditions.

The resins to be treated are polystyrene based with quaternary aminos in the case of the anion exchanger respectively sulphonic acid in case of the cation exchanger. Depending on temperature and oxidization conditions, the gas passing through the decomposition chamber will contain sulphur oxides and aromatics besides nitrogen oxides, carbon oxides and water.

The temperature at the bottom plate of the decomposition chamber is adjusted to about 600°C. The burner temperature is kept below 800°C to minimize cesium volatilization. The temperature in the secondary burner rises to 900 C to complete the decomposition of the gaseous components and to complete oxidization. Radioactive aerosols, sulphur oxides and nitrogen oxides will be retained in the off-gas line.

Laboratory experiments on the thermal decomposition of the resins will support the developmental work with the pilot plant. Their results will either underline the experimentally found temperature gradient to be adjusted along the decomposition chamber or will provide data for a further optimized design.

The influence of the temperature on the off-gas composition, especially on the volatilization of the radioactive species will be detected. A suitable temperature profile along the burner and the following off-gas line has to be defined, which allows for concentration of the radioactivity in only one of the secondary waste streams, preferably in the ash.

ECONOMY

A comparison on the basis of 250 tons of resins to be treated per year has been made. It includes estimated capital costs, costs for operating, packaging and disposal. The German principles for the management of radioactive waste have been taken into consideration. That means disposal of the waste in deep geological formations according to the acceptance criteria for final waste packages to be disposed of in the Konrad site (2).

Figure 2 shows that disposal costs and packaging costs are dominant compensations even for the high capital costs needed in the case of incineration. Hot pressing was found to be the most economical process closely followed by incineration. If high chemical stability of the final product is required in addition to good economy, incineration is the best option.

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